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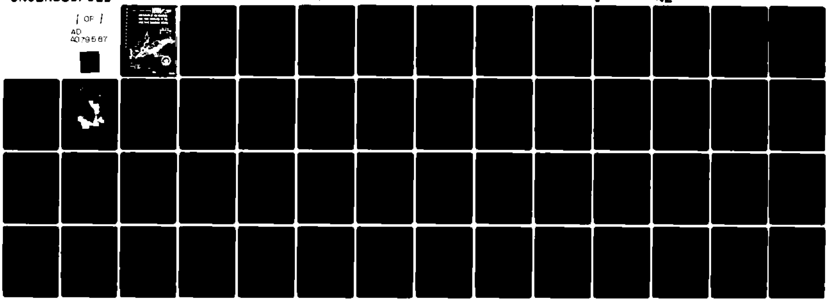

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This report described the procedures used to determine potential gross erosion (PGE) in the U. S. portion of the Lake Erie drainage basin. The Universal Soil Loss Equation (USLE) was used in conjunction with the LEWMS-developed Land Resources Information System (LRIS) to determine gross erosion in the basin under existing conditions, and to evaluate the effect on gross erosion of several crop management options. These options included: reduce all soil

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losses to T (soil loss tollerance value), ban fall plowing, use winter cover crop, reduce tillage (chisel plow, disc, etc.), and conservation tillage (no-till on better-drained soils, chisel plow on soils with intermediate drainage). The report describes development of the USLE variables and gives samples of the output which is published as an appendix to this report.

APPLICATION OF THE UNIVERSAL SOIL LOSS EQUATION IN THE LAKE ERIE DRAINAGE BASIN

(12)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This report described the procedures used to determine potential gross erosion (PGE) in the U.S. portion of the Lake Erie drainage basin. The Universal Soil Loss Equation (USLE) was used in conjunction with the LEWMS-developed Land Resource Information System (LRIS) to determine gross erosion in the basin under existing conditions, and to evaluate the effect on gross erosion of several crop management options. These options included: reduce all soil losses to T (soil loss tolerance value), ban fall plowing, use winter cover crop, reduced tillage (chisel plow, disc, etc) and conservation tillage (no-till on better-drained soils , chisel plow on soils with intermediate drainage). The report describes development of the USLE variables and gives samples of the output which is published as an appendix to this report.

INTRODUCTION

The Lake Erie Wastewater Management Study (LEWMS) has been underway in the Lake Erie Basin since 1974, under the direction of the Buffalo District, U.S. Army Corps of Engineers. Authorized by Public Law 92-500, Section 108 (d), the study has focused on the input of pollutants to the lake from the surrounding drainage basin, some 23,000 square miles in the U.S. portion alone. The study has several objectives, discussed more fully in other reports (LEWMS, 1975, 1978),but the primary objective is to identify major sources of pollution to the lake and structure a plan by which water quality in Lake Erie can be restored and maintained. During Phase I and II of the study, it became apparent that non-point sources of phosphorus in tributary loads accounted for a significant part of the total P loading to Lake Erie, and that a significant portion of this load would have to be reduced in order to achieve a reasonable water quality in the Lake. It was then realized that a comprehensive data analysis system was needed to quantify the land use of the basin and also some tool to estimate the impact of land use on non-point source phosphorus. This led to development of the LRIS (Land Resource Information System) which has been discussed in detail elsewhere (Cahill, 1979).

Stream monitoring in Phase I of the study (LEWMS, 1975) showed that a high percentage (70-85%) of the total P load in streams draining to Lake Erie is particulate P and that much of this sediment-bound P is of soil origin, generated during erosion events. It was, therefore, felt that estimates of soil loss in the basin using the Universal Soil Loss Equation (USLE) would help identify those areas which, because of land use or soil type, contributed to this erosion and resulting sediment and sediment-bound P discharged to the Lake.

The USLE was also used to estimate the potential impact on gross erosion of implementing a range of conservation practices in the cultivated crop production areas of the basin.

LAND RESOURF INFORMATION SYSTEM

It was determined early in 1976 that a Land Resource Information System (LRIS) would be developed during Phase II of the LEWMS Study. This data base had to spatially express the existing natural and cultural features within the Lake Erie basin in a format that would satisfy the various study objectives.

It would have been impossible to complete development of the data base for the Lake Erie basin if major sections had not already been completed by other agencies. These existing data base sets, including the Toledo Metropolitan Area Council of Governments (TMACOG), Southeast Michigan Council of Governments (SEMCOG) and the State of Ohio's Capability Analysis Program (OCAP) (Figure 1), serve as the foundation of this system and were integrated with the remaining portions of the basin. While various details are slightly different within each system, the basic structure and composition is sufficiently similar to allow the merging of data systems.

LRIS is a variable cell-size multiparameter system for encoding spatial data by a random point/cell digitizing procedure. That is, each cell or unit of land surface (varying from 4 to 36 hectares) is encoded for each parameter (soil phase, land use, etc.) at a randomized point location within each cell.

The LRIS includes information on the two principal land-related factors: LAND USE and SOILS. It also provides two ways of spatially defining the data: both watershed boundaries and political boundaries are coded. In order to minimize costs of data collection, the size of grid cells varies over the

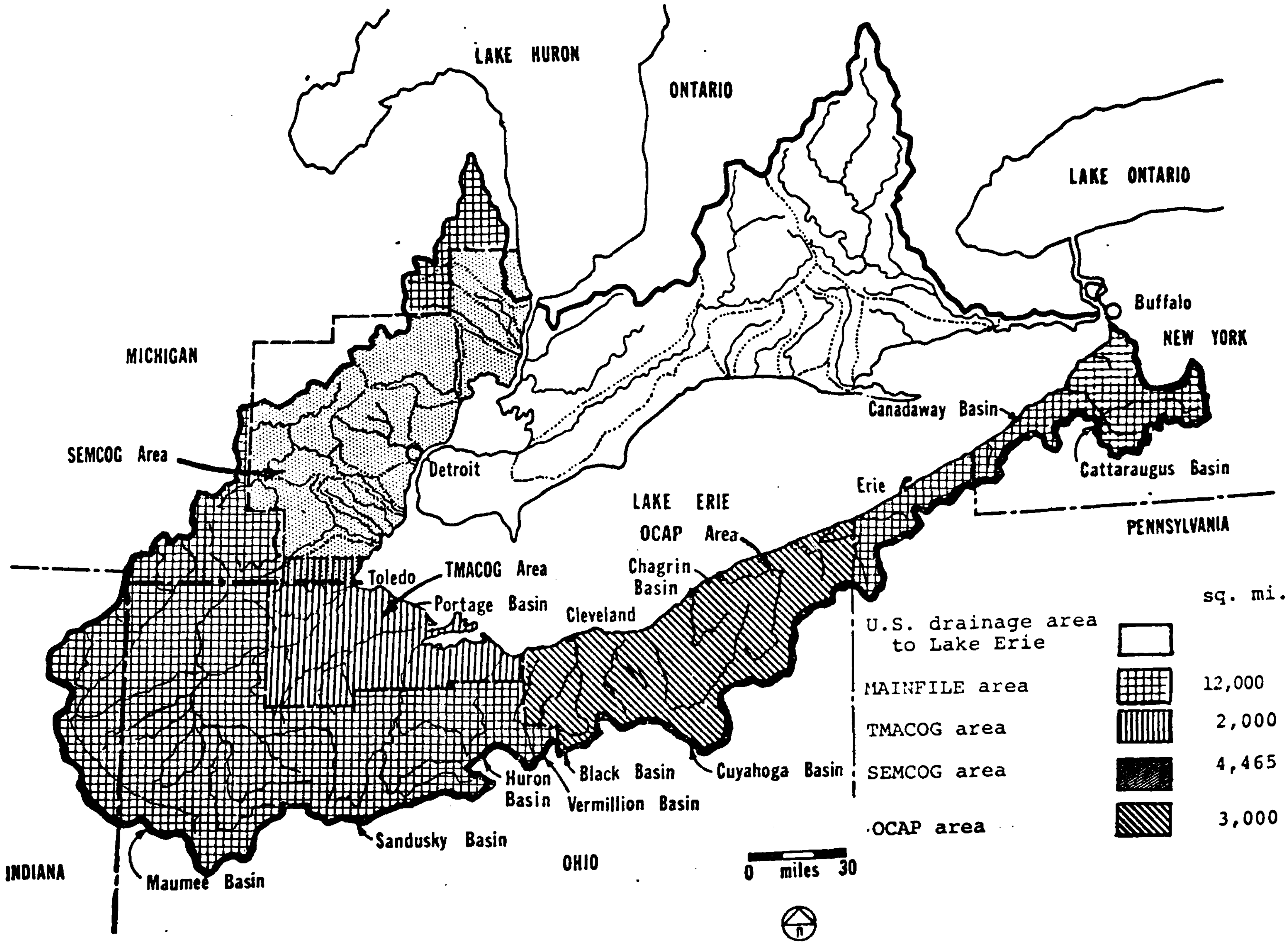

Figure 1. Sources of Data for Land Resource Information System (LRIS).

basin, depending primarily on the size of drainage basins above chemical sampling stations (Figure 2) but also on the complexity of data encoded. Thus the Sandusky basin tributary, Honey Creek, a pilot research project area with sub-basins of less than 15 mi^2, was coded at 4 hectares and the Auglaize basin (2900 mi^2), tributary of the Maumee River was coded at 36 hectares. The smallest cells are those comprising the TMACOG system (4 hectares) and the largest (36 hectares) were used in much of the Maumee River basin.

Existing data, which has been computer coded by other governmental units, has been used as much as possible. There are thus four sources of the data base:

1. TMACOG (Toledo Metropolitan Area Council of Governments) uses a 200 meter/UTM grid and includes data on land use, soils, watershed, and political unit.
2. SEMCOG (South East Michigan Council of Governments) uses a 660 foot grid referenced to State Plane coordinates and includes data on soils, watersheds, political units and land use. Much of the original data was digitized as polygons and converted to cells in this study.
3. OCAP (Ohio Capability Analysis Program by ODNR) uses a line digitizing method which has been converted to approximately a 9 hectare cell. It is not tied directly to any coordinate system, but rather orientation is based on latitude. Data is included on land use, soils, watershed, and political unit.
4. COE Main File (Corps of Engineers), uses a variable cell size with either 200, 400, or 600 meter cells. Reference is to the UTM coordinate system. Data is included on land use, soils, watershed and political unit.

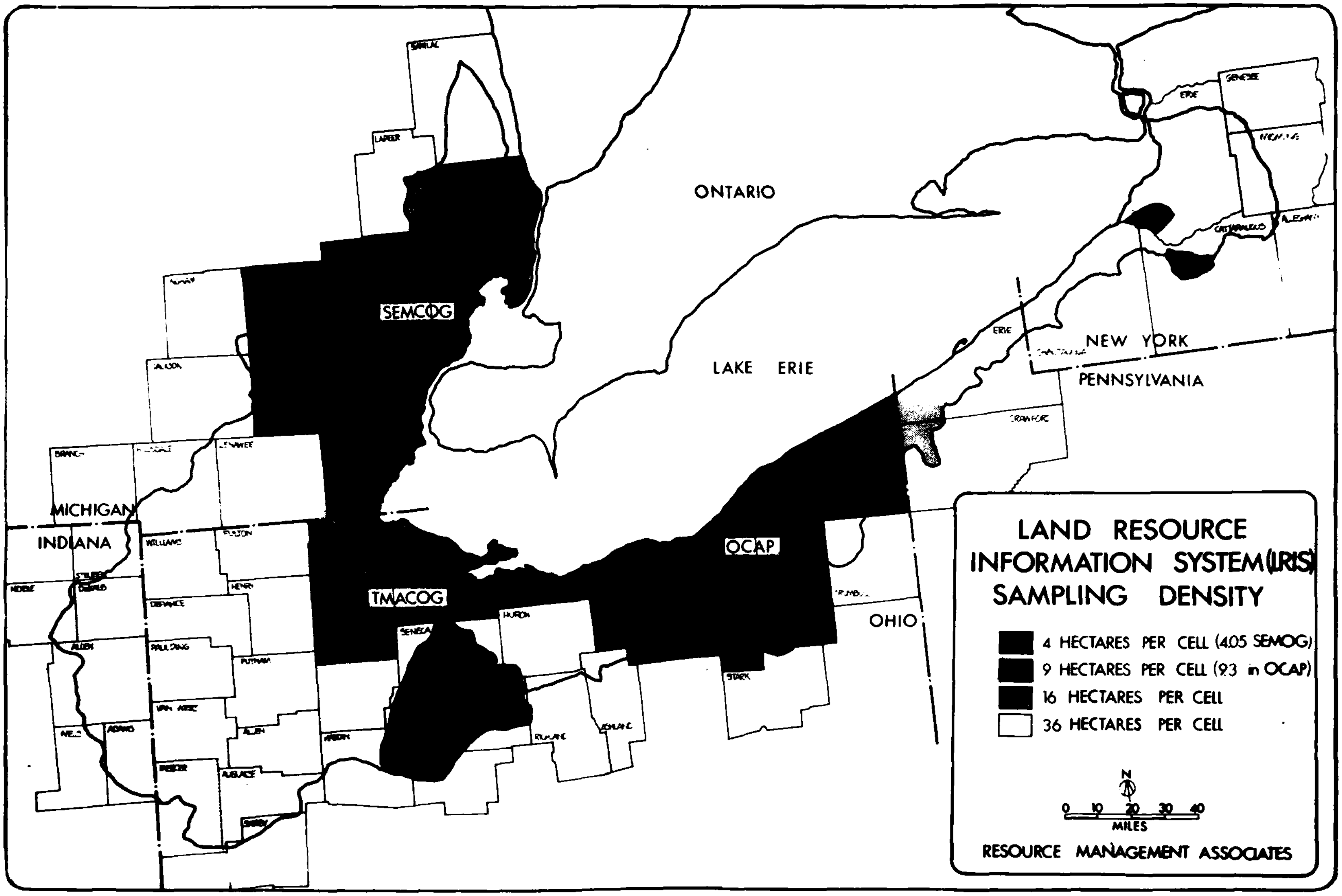

Figure 2. Variable cell sizes in the LRIS.

The data base will be maintained in two principal forms: one suitable for making maps, and the other suitable for making tabular summaries.

In mapping form, the grid cell structure will be maintained. The spatial position of a piece of data is referenced by its position in any array.

In the tabular form, the spatial position is no longer retained. All points which have the same attributes are added together. The resulting file requires fewer pieces of data and results in more efficient computer processing.

Land Cover File

Photointerpretation

The emphasis on diffuse sources of phosphorus generation in the LEWMS Study dictated that the LRIS describe existing land use, and in particular, agricultural land use, throughout the lake basin.

Photointerpretation of high altitude infrared photography was the primary data source to digitize land use information for the LRIS. In June 1976, color infrared photography covering the Sandusky Basin and contiguous watersheds (approximately 200 mi^2) was photographed by NASA Lewis, Cleveland, at a 1:70,000 scale. This data was photointerpreted by The Environmental Research Institute of Michigan (ERIM) using a relatively dense grid of 4 hectare cells (200 meters per side) for portions of the basin, and 9 hectare cells for the balance. The Honey Creek Basin (Fig. 2), 177 mi^2 of the Sandusky Basin above Fremont was done as a pilot effort at the 4 hectare density (11,483 cells), and the balance of the area finished primarily at the 9 hectare density.

The balance of the Lake basin has also been photographed (color IR) by NASA, Cleveland, Ohio at a 1:120,000 scale. The land use photointerpretation of this data was done at varying densities, either 16 or 36 hectare cells.

Land Use/Land Cover Coding Scheme

Land use/cover information is included in the LRIS data base for all areas of the Lake Erie drainage basin. While the coding scheme used to digitize cover information in the TMACOG file and CORPS main file areas was nearly identical, the OCAP coding scheme was significantly different, as was the SEMCOG scheme. A new coding scheme which is consistent across all four data sources has been created.

Since the codes for the TMACOG and main file schemes were so similar, (Haack, 1977) they have been used as the base and the OCAP coding scheme was "fit" into them. Two simple rules were sufficient to fit the OCAP codes:

1. When an OCAP category matched closely with an ERIM category, the OCAP code was simply replaced by the ERIM code in the data base.
2. When an OCAP category did not match closely enough with an ERIM category, a new code member was added to the ERIM coding scheme and the OCAP code was assigned this number. If a new code number was necessary, the number chosen fell as closely within ERIM's overall coding structure as was possible.

Table 1 lists the final categories and land use code numbers used in the data base. The OCAP data actually used two separate coding schemes, one for land use and one for land cover. A county was coded either for land use or land cover, but not both. For the USLE analysis, all point-cell data was converted into one of the 88 categories in Table 1 using best available information for interpretation.

Table 1. Land use code summary

LRIS Land Use No.	Land Use Description
8	Commercial-industrial, undifferentiated
9	Mixed Urban or builtup land
10	Residential, undifferentiated
11	Residential, Single Family: detached houses on individual lots in an urban, suburban, strip or cluster development area.
12	Residential, Multiple Family: apartments, townhouses or row houses
13	Mobile Home: large trailer park or single unit
14	Commercial and services: central business districts, shopping centers, commercial strips and sales or service facilities
15	Industrial: light to heavy manufacturing, mills, plants
16	Institutional: Educational, religious, health, correctional and military facilities, including all grounds
17	Extractive: sand and gravel pits,quarries, wells, and mines
18	Open Space: Golf courses, parks, cemeteries and undeveloped urban land
19	Other Urban: Urban areas of less intensive or nonconforming uses which are not covered above, such as land fill areas
20	Disrupted Cropland: Cropland with major irregular patterns of unvegetated areas
21	Cropland, Undifferentiated: Land use to produce agricultural crops
22	Truck Crops: Large agricultural fields
23	Orchards and bush-fruit areas

Table 1. Continued

LRIS Land Use No.-	Land Use Description
24	Horticulture: includes nurseries, ornamental shrubbery, floricultural areas, and seed-and-sod areas
25	Old Field Vegetation: farm land not currently being used for production
26	Feedlots: chiefly beef cattle feedlots and large poultry farms
27	Farmsteads: land used for buildings associ-ated with agricultural production
28	Other Agricultural Land: agricultural land not included in the preceding categories
29	Row Crop: Corn, soybeans, etc.
30	Field Crop: Small grains, cover crops
31	Brushland: Land covered with woody vegetation
32	Strip Cropping: Alternate crop types in strip pattern.
41	Deciduous Forest: deciduous forest includes all forested areas in which the trees are predominantly hardwood
42	Coniferous Forest: coniferous forest includes all forested areas in which the trees are predominantly those with needle foliage.
43	Mixed Forests: Mixed forest land includes all forested areas where both deciduous and coniferous trees are growing and neither predominates
44	Forest or grassland: undifferentiated
45	Forest: undifferentiated, type not determined
51	Rivers and Streams: includes rivers, streams, creeks, canals, drains and other linear bodies of water

Table 1. Continued

LRIS Land Use No.	Land Use Description
52	Lakes: Lakes are non-linear water bodies, excluding reservoirs
53	Reservoirs: Reservoirs are artificial impoundments of water
54	Bays and Estuaries
55	Water or Marshland: undifferentiated
61	Wetland, Forested: Seasonally flooded basins and flats, meadows, marshes and bogs
62	Wetlands, Non-Forested: Same as above, but less than 25% tree cover
71	Beaches, Mudflats, Unvegetated Areas: the sloping accumulations of sand and gravel along shorelines
72	Construction Activity: Land which is barren due to clearing operations associated with construction activity
73	Sandy Areas Other Than Beach
74	Bare Exposed Rock
75	Barren/Abandoned Mines, Quarries
76	Exposed Rock/Sandy Areas: undifferentiated
81	Improved Roads: all paved roads and highways
82	Unimproved Roads: Gravel, oiled and dirt roads.
83	Railroads: All facilities connected with rail transportation, including rights-of-way
84	Airport: All facilities directly connected with airports
85	Utilities: Areas associated with the transport of gas, oil, water or electricity
86	Shipping Ports: Facilities connected with commercial shipping transportation
87	Utility and Rail Row: undifferentiated, either 83 or 85.
88	Transportation: undifferentiated

Soils File

Probably the most important natural feature determining the amount of sediment and runoff generated by agricultural and other land use activities is the soil on which these activities are located. Soils information is therefore the most critical element of the LRIS.

Soil Conservation Service (SCS) soil survey information is the primary data source for soil series information. SCS maps soil series information on a county basis. Approximately half of the county surveys are in published form, but nearly all of the remainder are underway. This limitation of available data was mitigated in two ways:

1. Incomplete information has been related to more complete soil series information in neighboring counties to fill in some gaps during subsequent updating of the file. This involved the use of individual farm surveys where they existed, soil association data for Lucas, Sandusky and Ottawa counties in Ohio, and updating of old series names to probable current series.
2. Arrangements were made with SCS offices to complete series mapping in small areas.

Soil information in the LRIS is found in three parts. First, the digitized soils data file stores a soil phase code at each point/cell in the study area. Soil phases (soil type, erosion phase and slope phase) were encoded in each county. To facilitate processing of this information, LRIS has converted the alphanumeric soil phase symbols coded from the maps into a set of numeric phase codes in the data base. These numeric codes are used to access the second part of the LRIS soils data -- the Phase File.

The Phase File stores some general information about each phase number encountered on the digitized soil data file, as well as information necessary to access the detailed soil properties for each phase. Table 2 is a list of the information in the Phase File.

Table 2. Information in the LRIS Phase File

1. LRIS phase number.
2. SCS soil series name.
3. SCS soil phase mapping symbol.
4. Soil surface texture
5. County in which the phase is found.
6. Slope of the soil type.
7. Soil Properties File pointer.

Soil Properties File

The soil Phase File, as discussed in the preceding sections, was developed from the digitized soils data for each county in the LRIS. Thus the same soil type and slope phase could occur in several counties and appears in the phase file several times. By sorting the file on "name-surface texture (type)-slope", the 8,700 records were reduced to a shortened file of 3,131 unique phases. These 3,131 records were called "pointers", because they point to a unique set of soil properties in the Soil Properties file.

The Soil Properties file was derived from the SCS-5 National Properties files to produce a compact compilation of data necessary for water resources management and planning. The original SCS-5 data included more than 7000 characters of information. This was reduced to 380 characters of pertinent data. In addition to data from the SCS-5 files several other soil properties were added, including a reduced tillage soil management group, special drainage class code, slope length and a calculated LS factor.

The development of this file required numerous decisions with respect to the various soils properties, with a great deal of guidance provided by SCS soil scientists in the Lake Erie basin and computer experts at the Statistical Laboratory, Ames, Iowa. An example of information extracted from the Soil Properties file for Crawford County, Ohio is given in Table 3. This table is an example of the county soil properties report. It does not include data for horizons beyond the "A" horizon nor does it include any of the crop yield data.

Table 3. An example of the Soil Properties File for Crawford County, Ohio.

COUNTY SOIL PROPERTIES REPORT FOR: 2 02 CRAWFORD, OHIO

NAME	TEXT	SYMB	SLOPE	SLEN	KFAC	LSFAC	TFAC	ERCD	SMG	CCLS	DRNG	PERM	DSHWT	DTBR
ALEXANDRIA	SIL	AD	0-02	150.	.37	0.14	5	1	1	2E	WD	0.6 -2.0	6.0->	60->
	SIL	ADB	2-06	175.	.37	0.50	5	1	1	2E	WD	0.6 -2.0	6.0->	60->
	SIL	ADC	6-12	150.	.37	1.44	5	1	1	3E	WD	0.6 -2.0	6.0->	60->
	SIL	ADD2	12-18	150.	.37	3.14	5	2	1	4E	WD	0.6 -2.0	6.0->	60->
	SIL	ADE	18-25	150.	.37	5.84	5	1	10	6E	WD	0.6 -2.0	6.0->	60->
BENNINGTON	SIL	BG	0-02	230.	.43	0.15	3	1	2	2W	SPD	0.6 -2.0	0.5-1.5	60->
	SIL	BG	0-02	230.	.43	0.15	3	1	2	2W	SPD	0.6 -2.0	0.5-1.5	60->
	SIL	BGB	2-06	215.	.43	0.54	3	1	2	2E	SPD	0.6 -2.0	0.5-1.5	60->
BENNINGTON-X	509	702	3133											
BLOUNT	SIL	BO	0-02	230.	.43	0.15	3	1	2	2W	SPD	0.6 -2.0	1.0-3.0	60->
	SIL	BO	0-02	230.	.43	0.15	3	1	2	2W	SPD	0.6 -2.0	1.0-3.0	60->
	SIL	BOB	2-06	215.	.43	0.54	3	1	2	2E	SPD	0.6 -2.0	1.0-3.0	60->
BOGART	L	HA	0-02	175.	.32	0.14	3	1	2	2S	MWD	0.6 -2.0	1.5-3.0	60->
BONO	SICL	BP	0-02	340.	.28	0.12	5	1	4	3W	VPD	0.2 -2.0	0 -0.5	60->
CARDINGTON	SIL	CD	0-02	175.	.37	0.14	5	1	1	1	MWD	0.6 -2.0	2.0-3.0	60->
	SIL	CDC	6-12	150.	.37	1.44	5	1	1	3E	MWD	0.6 -2.0	2.0-3.0	60->
	SIL	CDD	12-18	125.	.37	2.86	5	1	1	4E	MWD	0.6 -2.0	2.0-3.0	60->
	SIL	CDE	18-25	100.	.37	4.77	5	1	10	6E	MWD	0.6 -2.0	2.0-3.0	60->
CARDINGTON-X	525	702	3133											
CARLISLE	MUCK	CF	0-02	310.	.10	0.10	2	1	5	5W	VPD	0.2 -6.0	0 -1.0	60->
UNDEFINED	527	780	3141											
CHILI	L	BE	0-02	150.	.32	0.14	4	1	1	2S	WD	0.6 -2.0	6.0->	60->
	L	BEB	2-06	175.	.32	0.50	4	1	1	2E	WD	0.6 -2.0	6.0->	60->
	L	BEC	6-12	160.	.32	1.48	4	1	1	3E	WD	0.6 -2.0	6.0->	60->
	L	BED2	18-25	100.	.32	4.77	4	2	10	6E	WD	0.6 -2.0	6.0->	60->
COLWOOD	SIL	CO	0-02	310.	.28	0.10	5	1	2	5W	VPD	0.6 -2.0	0 -1.5	60->
	SIL	COB	2-06	200.	.28	0.53	5	1	2	5W	VPD	0.6 -2.0	0 -1.5	60->
	SIL	COC2	6-12	150.	.28	1.44	5	2	2	5W	VPD	0.6 -2.0	0 -1.5	60->
CONDIT	SIL	CY	0-02	200.	.37	0.14	5	1	3	3W	PD	0.6 -2.0	0 -0.5	60->
	SIL	C12	0-03	200.	.37	0.22	5	1	3	3W	PD	0.6 -2.0	0 -0.5	60->
CONDIT-BENNI	538	700	3132											
CONDIT-BENNI	537	700	3132											
CUT & FILL	539	710	3134											
DEL REY	SIL	DE	0-02	300.	.43	0.16	3	1	3	2W	SPD	0.6 -2.0	1.0-3.0	60->
DUMPS	541	710	3134											
ELLIOTT	SIL	BT	0-02	200.	.28	0.14	4	1	2	2W	SPD	0.6 -2.0	1.0-3.0	60->
	SIL	ET	0-02	200.	.28	0.14	4	1	2	2W	SPD	0.6 -2.0	1.0-3.0	60->
FITCHVILLE	SIL	FC	0-02	190.	.37	0.14	5	1	2	2W	SPD	0.6 -2.0	0.5-1.5	60->
	SIL	FCB	2-06	175.	.37	0.50	5	1	2	2E	SPD	0.6 -2.0	0.5-1.5	60->
GALLMAN	SIL	TM	0-02	200.	.32	0.14	5	1	1	1	WD	2.0 -6.0	6.0->	60->
GLYNWOOD	SIL	MR	0-02	150.	.43	0.14	3	1	1	2E	MWD	0.6 -2.0	1.5-3.0	60->
	SIL	MRC	6-12	190.	.43	1.62	3	1	1	3E	MWD	0.6 -2.0	1.5-3.0	60->
	SIL	MRD2	12-18	150.	.43	3.14	3	2	1	4E	MWD	0.6 -2.0	1.5-3.0	60->
GRAVEL PIT	554	710	3134											
HENNEPIN	SIL		18-25	150.	.32	5.84	4-3	1	10	6E	WD	0.6 -2.0	6.0->	60->
	SIL		18-25	150.	.32	5.84	4-3	1	10	6E	WD	0.6 -2.0	6.0->	60->
HENNEPIN-ALX	555	700	3132											
ILLEGIBLE	556	790	3142											
JIMTOWN	L	DM	0-02	250.	.32	0.15	4	1	2	2W	SPD	0.6 -2.0	0.5-1.5	60->
	L	DMB	2-06	200.	.32	0.53	4	1	2	2E	SPD	0.6 -2.0	0.5-1.5	60->
KIBBIE	FSL	KB	0-02	150.	.20	0.14	5	1	2	2W	SPD	0.6 -2.0	1.0-2.0	60->
	FSL	KB	0-02	150.	.20	0.14	5	1	2	2W	SPD	0.6 -2.0	1.0-2.0	60->
	FSL	KBB	2-06	200.	.20	0.53	5	1	2	2E	SPD	0.6 -2.0	1.0-2.0	60->
KIBBIE-BENNT	562	700	3132											
LENAWEE	SICL	LS	0-02	500.	.28	0.11	4	1	4	5W	VPD	0.6 -2.0	0 -1.0	60->
	SICL	TO	0-02	500.	.28	0.11	4	1	4	5W	VPD	0.6 -2.0	0 -1.0	60->
LOBDELL	SIL	LO	0-02	120.	.32	0.10	5	1	5	2W	MWD	0.6 -2.0	1.5-3.0	60->

NAME: Soil series TEXT: Soil textural code SLOPE: Slope percentage range

SLEN: Slope length (feet) KFAC: USLE soil erodibility factor
LSFAC: USLE slope percentage-length factor TFAC: Allowable soil loss (1-5 tons/acre/year)

ERCD: Erosion class SMG: Soil management group
CCLS: Land use capability class DRNG: Drainage class
PERM: Permeability (inches/hr) DSHWT: Depth (feet) to seasonal high water table

DTBF: Depth (feet) to bedrock

Bennington - x 509 702 3133: Complex of Bennington series for which there are no properties in the file. The three numbers are: phase, series reference and pointer.

LRIS Variables

The information as encoded in the LRIS can describe a selected basin or land area in two different ways. First, the composition of a basin in terms of a selected variable, such as land use, can be summarized by the percentage of different types of land use (i.e., 72% agricultural land) as a function of the basin as a whole. For a variable such as slope, the different categories (ranging from 0.2% to 35%) can be stated, or an average slope value calculated based on the basin composition. (See Table 5). For soil-derived characteristics, such as permeability, texture, erodibility or drainage class, the ranges of values are grouped and ranked according to some scheme (See Table 3 for example).

Table 3 also lists other descriptive variables: erosion class (ERCD), land use capability class (CCLS), drainage class (DRNG) (WD = well drained, SPD = somewhat poorly drained, etc), permeability (PERM), depth to seasonal water table (DSHWT) and depth to bedrock (DTBR). Although these parameters are useful for many types of interpretation, the soil parameters used in the USLE anlaysis are of particular importance and are discussed in detail in the next section.

DEVELOPMENT OF USLE DATA

The Universal Soil Loss Equation (USLE) was developed by USDA-ARS to predict long-term annual soil loss (Wischmeier and Smith, 1978). The equation in its simplest form is a linear function which relates gross erosion to climatic, soil and vegetation conditions:

$$A = RKLSCP$$

A = annual soil loss (tons/acre)   R = Rainfall erosion index

K = Inherent soil erodibility   LS = Combination of slope percentage and slope length

C = Cover and management factor   P = Conservation practice factor

In using the USLE with LRIS to give distributed estimates of annual gross erosion in the L.E. basin, some of the factors were derived from the soils data file (LRIS) while others were computed from regional information.

- R factor data was taken from USLE Handbook 282 and developed on a county basis.
- K factors were taken from LRIS soils file by soil type.
- Slope percentage, S, was developed from LRIS soil phase data by taking the median value for slope range given. Slope length was estimated from local SCS experience and the recent 1% National Erosion Survey.
- C factors were developed from county-level estimates of crops grown; rotations were developed for each county based on local interpretation.
- P factor was assumed to be 1, i.e. there were no supporting conservation practices.

The equation was run initially with the assumption that only conventional tillage practices were used. Several scenarios in which some form of conservation tillage or other means of reducing gross erosion were also run. Development of data for each of the factors is discussed next.

Rainfall Erosion Index

Rainfall erosion index data is given in Handbook 282 (Wischmeier and Smith, 1965) in the form of annual isoerodent lines. This data was used directly in the analysis, but interpolated to give a single value for each county in the basin. Figure 3 shows the isoerodent lines for this analysis which vary from a low of 75 in the northern reaches of the basin to a high of 150 in the southwest corner. Most of the basin has R values between 100 and 138. Table 4 also gives the actual R values used for each county.

Soil Erodibility

Soil erodibility (K) values were developed by USDA scientists for soils of the U.S.. They constitute part of the soil properties (S-5) record, and is part of the LRIS point cell file (Table 3). Therefore, in the USLE analysis reported here, soil erodibility was determined from individual point cell data.

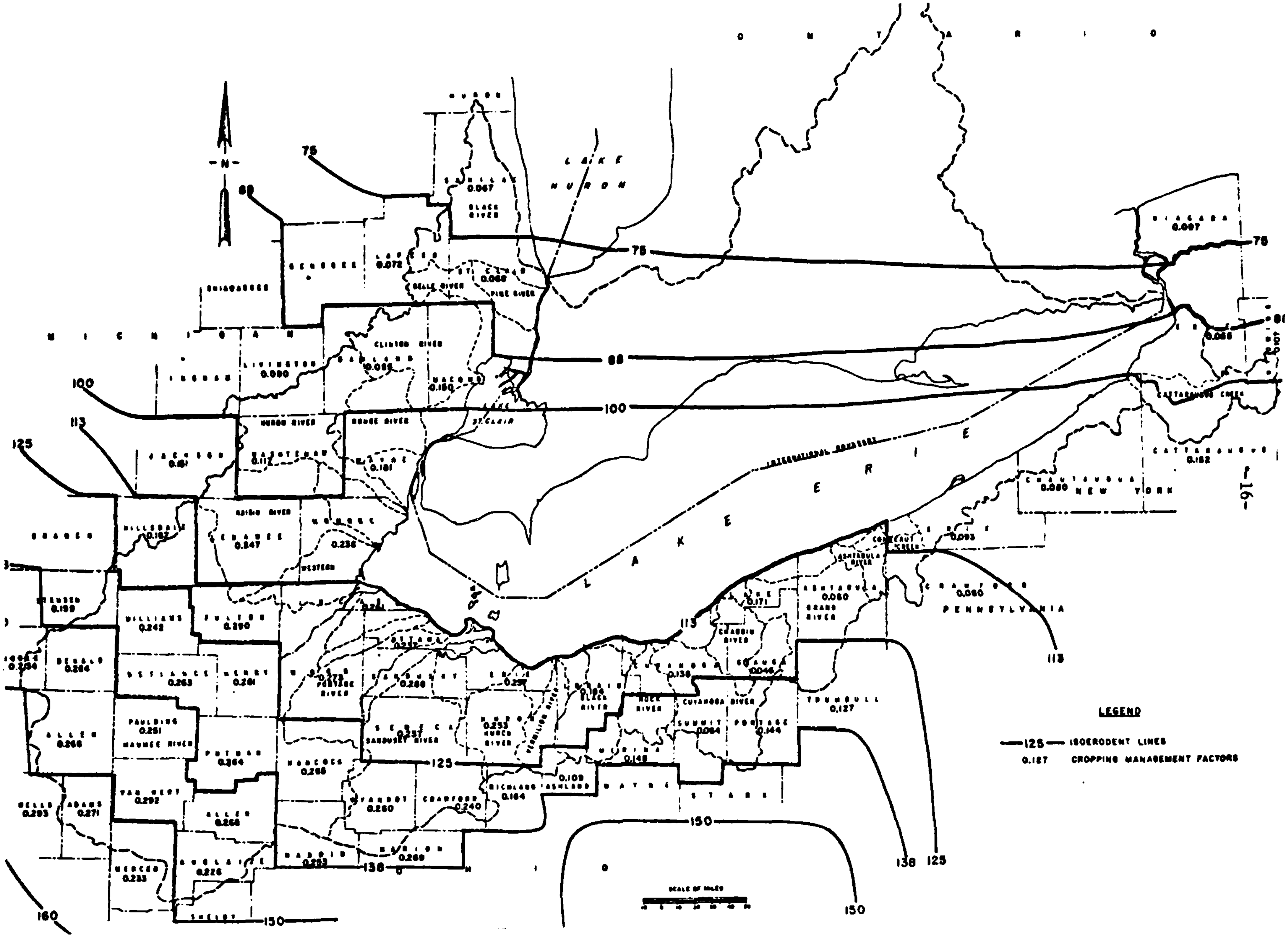

Figure 3. Annual rainfall isoerodent lines (R factor) for L. Erie Basin counties. County C factors are also given.

Table 4. Rainfall erosion index (R) values for each county.

County	R Value	County	R Value
		Ohio	
Allen	150	Richland	138
Defiance	138	Sandusky	125
Fulton	125	Seneca	125
Hancock	138	Wyandot	138
Henry	138	Ashtabula	125
Lucas	125	Geauga	125
Paulding	150	Lake	125
Putnam	138	Medina	138
Van Wert	150	Portage	138
Williams	138	Summit	138
Wood	125	Trumbull	138
Ashland	138	Auglaize	150
Crawford	125	Hardin	138
Erie	125	Mercer	160
Huron	125	Marion	138
Lorain	125	Cuyahoga	125
Ottawa	125		
		Michigan	
Monroe	113	Livingston	100
Lenawee	113	Oakland	100
Hillsdale	125	MaComb	100
Wayne	113	Lapeer	88
Washtenaw	100	St. Clair	88
Jackson	113	Sanilac	75

Table 4 (Continued).

County	R Value	County	R Value
	Indiana		
Allen	150	Noble	150
Adams	160	Steuben	138
DeKalb	150	Wells	160
	Pennsylvania		
Crawford	138	Erie	125
	New York		
Cattaraugus	113	Wyoming	100
Chautauqua	113	Niagara	75
Erie	100		

Conservation Practices

Widespread use of conservation practices such as contour strip cropping, terraces, etc., is not common in the Lake Erie drainage basin. Statistical information on the distributed use of these practices is not readily available, and although they are used to some limited extent throughout the basin, they were assumed to be negligible and the P factor was assigned a value of one.

Slope and Slope Length

The use of the USLE on the data within the LRIS file required that a degree of slope and a slope length be assigned. This required that an arbitrary number be selected that would represent a slope phase group, and for each soil series and slope phase that a slope length be assigned. At the level of detail of this study this meant that the same soil series and slope phase would be assigned the same percent slope and slope length wherever it occurred in the basin. It should be recognized that, in areas of high drainage density, slope lengths for the same soil series and slope phase will typically be shorter.

The degree of slope in high drainage density areas for the same soil series will be dominantly higher also. For example, a soil on a till plain may occur dominantly on "A" slopes,whereas close to streams it may tend to occur on "B" slopes. When used in the USLE, the factor will tend to equalize and should not bias the results. Since the object of the study is to prioritize problem basins, this should not introduce a major error in determining potential erosion. It will be a consideration in any on-the-land studies, however.

Slope Percentage

A median slope percentage was assigned according to Table 5. There were modifications to this for flood plains, mucks and very poorly drained soils which are very flat or depressed on the landscape. Flood plain soils were assigned slope percentages that recognize the stream gradient. Some

Table 5. Assignment of percent slope from detailed soil surveys.

0-2 = 1
0-3 = 2
0-4 = 2
0-5 = 3
0-6 = 3
0-8 = 4
0-10 = 5
0-12 = 6
0-15 = 8

1-3 =2
1-4 = 3
1-5 = 3
1-6 = 4
1-8 = 6

2-4 = 3
2-5 = 3
2-6 = 4
2-7 = 5
2-8 = 6
2-12 = 7
2-18 = 10
2-25 = 13

3-5 = 4
3-6 = 4
3-7 = 5
3-8 = 6
3-12 = 8

4-10 = 7
4-12 = 8

5-10 = 8
5-15 = 10
5-25 = 15

6-12 = 9
6-15 = 10
6-18 = 12
6-19 = 12

7-14 = 10
7-15 - 11

8-15 = 11
8-18 = 13

10-15 = 12
10-20 = 15
10-40 = 25

12-16 = 14
12-18 = 15
12-20 = 16
12-25 = 18
12-45 = 28
12-50 = 31

14-25 = 19
14-99 = 35

15-25 = 20
15-30 = 22
15-35 = 25
15-99 = 35

18-25 = 22
18-30 = 24
18-35 = 26
18-40 = 29
18-50 = 34
18-60 = 35
18-99 = 35

20-30 = 25

25-35 = 30
25-40 = 32
25-45 = 35
25-50 = 35
25-60 = 35
25-70 = 35
25-99 = 35

30-40 = 35
30-45 = 35

35-50 = 35
35-70 = 35
35-99 = 35

50-99 = 35

*Muck
0-2 = .2
0-3 = 1

*Very Poorly Drained
0-2 = .2
0-3 = .5

*Flood Plain Soils
0-2 = .5
0-3 = 1
0-6 = 3

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*For all other slope phases, the assignments in the table were used.

unfamiliar soil types were referenced to the SCS Soils-5 Record, Official Soil Series Descriptions and the Classification of Soil Series of the United States for slope range and setting.

Experience with the USLE indicates that this equation is not reliable when used at very high slope percentages in arriving at potential soil movement. For this, and other reasons (some surveys only indicated slopes of 35% instead of giving the actual slope), the degree of slope for any slope phase in excess of 35 percent slope was held to 35 percent.

Slope Lengths

An important factor in the USLE is the length of slope. An extra effort was made to assign a realistic slope length to each soil series and slope phase. Several sources were used as a basis for selection. The following sources were used in the order listed:

A. Actual measured lengths compiled from all of the worksheets from the SCS 1% Erosion Study in all of the counties within the Lake Erie basin. Several thousand observations were recorded.

B. A survey of soil scientists and district conservationists was made. Each was asked for his best estimate of the typical slope lengths of the major soils occuring within the Akron-Cleveland 208 Planning Area.

C. Experience of Ohio State Soil Survey staff was considered.

D. Maumee River Level B Study (1975) was used for comparison of slope lengths used during that study.

E. Similar land forms, modes of deposition and natural drainage as contained in the SCS Soils-5 Record and official soil series descriptions were assigned similar lengths when other references were not available.

Confidence codes were also used so that future reviewers would have this benefit. The method used is as precise as present information available can provide. Improvements certainly can be made in the future.

The LS factor was then determined for each point cell according to the equation (USLE Handbook 282):

$$LS = (\lambda/72.6)^m \cdot (65.41 \sin \theta + 4.56 \sin \theta + 0.065)$$

where: λ = slope length (feet) and $\sin \theta = \frac{\%\ \text{slope}}{100}$

m = coefficient (In this study, m = 0.5 if slope is 5% or greater, 0.4 if slope is 4% and 0.3 if slope is 3% or less).

Soil Management Groups

In the development of conservation tillage or other management options to reduce soil loss, it was recognized that some practices are not suited to all soils. No-till is only suited to better-drained soils, and if used on heavier, more poorly-drained soils can result in crop yield reductions. Practices like chisel plowing or disking which leave some residue on the surface are adapted to a wider range of soil conditions than no-till, but are still unsuited to poorly drained conditions. Triplett et al (1973) developed a no-till suitability classification for Ohio soils and this system was used for all soils in the L.E. basin in studying conservation tillage practices (See "Scenarios" section). The Ohio classification used five soil management groups (SMG), and an additional five were added for the USLE analysis. A description of the 10 SMG's are given below.

Soil Management Group 1

With good management, soils included in this group should have yield response to no-till equal to or greater than conventional tillage. Soils in this group are moderately well, well, and excessively well drained or shallow. They have a silt loam, loam, sandy loam, or loamy fine sand surface texture. These soils are relatively low in organic matter and include glaciated, residual, and terrace soils. No recent alluvial soils are included.

Group 1 soils must have mulch cover for satisfactory no-till crop production. Mulch should cover 70 percent to 80 percent of the soil surface

at planting time. This can be old crop residue, drilled sod, dead weeds, or manure. If the site has less than 35 percent mulch cover, it should be tilled (disking and postplanting cultivation are satisfactory).

Soil Management Group 2

With good management, soils in this group should have yield response to no-till nearly equal to conventional tillage, provided soil drainage has been improved by surface or subsurface drainage. These soils are somewhat poorly to poorly drained in the natural state. They have a silt loam, loam, sandy loam, or loamy fine sand surface texture. Hydraulic conductivity (saturated permeability) is equal or greater than 0.2 inches per hour within the top two feet of the profile. Soils in this group are relatively low in organic matter and include glaciated, residual, and terrace soils. No recent alluvial soils are included.

Mulch cover is important to proper performance of no-till on lower organic matter soils (1.5 to 2.5 percent O.M.) in this grouping, as is the case with Group 1. No-till corn following sod, or delaying planting with no-till until the latter part of the optimum planting period in areas where continuous row cropping is practiced, are excellent choices on these soils.

Soil Management Group 3

Soils in this group may yield less with no-till in comparison to conventional tillage and should not be considered for no-till under most circumstances. These soils are somewhat poorly to very poorly drained. Hydraulic conductivity (internal water movement) is so slow that even tile does not provide adequate drainage. Surface texture is primarily loam, silt loam, or silty clay loam. These soils are derived from glacial till or residual parent material. No recent alluvial soils are included. Most of these soils are relatively low in organic matter content.

Soil Management Group 4

Soils in this group may yield less with a no-till system in comparison to conventional tillage. These soils are very poorly drained and have surface textures of silty clay loam, clay loam, silty clay, or clay. They contain relatively high amounts of organic matter in the surface. Soils developed in glacial till and residuum are included in this group, but alluvial soils are not. Corn on these soils does not respond to mulch cover where no-till is used, except perhaps for slower growth in cool, wet springs where mulch is present.

Soil Management Group 5

This group includes miscellaneous soils not recommended for no-till at this time. Included are organic soils, recent alluvial soils, strip mine land, and certian fine textured soils. There has been little or no experience with no-till on organic soils. Even with equivalent yields higher rates of herbicides required for weed control with no-till may make no-till a poor choice on organic soils. Corn grown on well-drained recent alluvial soils should respond satisfactorily to no-till, but in a small number of tests this has not been observed. No reason is known for the poor response at this time.

Yields on poorly drained clays, such as Paulding, have not been satisfactory with no-till. Well-drained soils where erosion has exposed a high clay subsoil probably should not be planted to row crops. No-till may do as well on these soils as any other system, but planter function with no-till has been a problem. Strip mine land is so variable that decisions for crop production must be made on an individual site basis.

Soil Management Groups 6-9

These groupings correspond directly to Groups 2 through 5. Group 6 responds to no-till cropping as does Group 2, Group 7 responds as does Group 3, etc. The division of each group is by surface texture classification. Groups 6-9 include all soils which might have been included in Groups 2-5, except that they have clay or silty clay surface horizon textures. The purpose for breaking out these fine-textured surface horizon soils involves the sediment phosphorus delivery characteristics of fine clays. Since such soils have been identified as having a more significant effect on water quality it is useful to know the degree to which a reduced tillage conservation program will be applied to them.

Soil Management Group 10

Group 10 includes all cropland on soils with slopes greater than 18 percent. This grouping was made because it is not recommended that lands with slopes of this magnitude should be in cropland. It was assumed that if these lands were presently in cropland, they would experience the lowest achieveable level of soil loss if a no-till management system were employed, and will typically still exceed "T".

Determination of Crop Management "C" Factors

Cropland

Crop management (C) factors were determined for each county in the basin according to the distribution of crop acreage in the county as provided by the U.S. Crop Reporting Service (Indiana, Michigan, Ohio). These were then combined to give three crop types:

R = Row crop (primarily corn and soybeans)
Sg = Small grains (wheat, oats, barley)
M = Meadow (hay and pasture)

Eight rotations were chosen to be representative of cropping conditions in the basin:

R Sg Sg M
R R Sg M
R Sg M
R Sg M M M
R R Sg
R Sg Sg M M
Continuous R
Continuous M

Crop management (C) factors were then determined using Handbook 282 and Ohio Erosion Control Guide (OCES, 1979) for fall and spring plowing, and assuming that crop residue was left on the ground after harvest. These factors are given in Table 6.

Table 6 . Crop management factors for rotations with fall and spring plowing.

Crop Sequence	Spring Plow Residue Left	Fall Plow Residue Left
RSgSgM	.070	.080
RRSgM	.120	.140
RSgM	.055	.070
RSgMMM	.035	.045
RRSg	.250	.270
RSgSgMM	.055	.060
Continuous R	.380	.430
Continuous M	.005	.005

For the present (existing) conditions scenario, an estimate was made by county of the percentage of cropland that was fall and spring plowed (Table 8). Three additional crop management options were considered:

a) Winter cover in RR and spring plowed. Other rotations treated as for existing conditions. This option was labeled "Winter Cover".

b) Plow the first-year following meadow (M); mulch-till thereafter in row crop (R) (disc, chisel, rotary, etc) with an average of 1500-2000 lbs/ac of residue left on surface; present conditions for other rotations. The amount of residue per acre is an average annual figure for the row crop part of the rotation and assumes corn-soybean rotation. This option was labeled "Mulch Tillage".

c) No-till methods used exclusively to give an annual average of 3000-4000 lbs/ac residue, and labeled "No-Till".

The adjusted C factors for these options are given in Table 7.

Table 7. C factors for eight crop rotations with variable cover.

Crop Sequence	Winter Cover	Mulch Tillage	No-Till
RSgSgM	.075	.075	.025
RRSgM	.105	.085	.030
RSgM	.065	.065	.030
RSgMMM	.040	.040	.020
RRSg	.210	.110	.040
RSgSgMM	.060	.060	.030
Continuous R	.320	.130	.030
Continuous M	.005	.005	.005

The next step was to assign or fit crop acreages in each county to the eight rotations. This was an iterative process which, for a high grain-producing county would be:

a) Assign all meadow acreage (M) to RRSgM
b) Assign remaining small grain (Sg) acreage to RRSg
c) Assign remaining row crop acreage to Continuous R

Where meadow (M) acreage was high, the sequence might be: RRSgMMM followed by RSgM or RRSg.

After assigning all cropland acreage to the rotations, an average "C" factor for the county was determined by weighting the individual "C" factors for the rotation by the acreage each represents. The following example for Allen County, Ohio will serve to illustrate:

1. Crop acreage (from Crop Reporting Service)

	Acres
Corn	66,900
Soybeans	67,900
Row crop (R)	134,600
Wheat	35,900
Oats	7,000
Small grains (Sg)	42,900
Hay	10,000

2. Selection of rotation and determination of average "C" factor.

Rotation	Acres per Rotation Sequence	Years of Rotation	Acres in Rotation	Area Weight Factor	"C" Factor	Area Weighted "C" Factor
RRSgM	10,000	4	40,000	0.213	0.12	0.025
RRSg	32,900	3	98,700	0.527	0.25	0.131
Cont. R	48,000	1	48,000	0.260	0.38	0.098
		TOTAL	187,500	1.000	--	0.254

The area weighted "C" factor, 0.254, is used in the USLE run for each soil on cropland in that county. Values for each county in the basin are given in Table 8 for the various scenarios.

Table 8 . Average county cover (C) factors for cropland.

County	Spring Plow Residue Left	Fall Plow Residue Left	Present Condition	Winter Cover	Conservation Tillage Mulch	No Till
		Ohio				
Allen	.254	.282	(50)*.268	.256	.108	.034
Defiance	.247	.270	(70).263	.249	.107	.036
Fulton	.275	.304	(50).290	.269	.111	.033
Hancock	.250	.275	(60).265	.252	.107	.034
Henry	.262	.289	(70).281	.260	.109	.034
Lucas	.249	.273	(50).261	.254	.108	.036
Paulding	.235	.255	(80).251	.243	.106	.038
Putnam	.250	.278	(50).264	.248	.107	.033
Van Wert	.277	.306	(50).292	.273	.112	.034
Williams	.230	.254	(50).242	.235	.104	.035
Wood	.256	.284	(60).273	.256	.109	.034
Ashland	.107	.126	(10).109	.109	.075	.030
Crawford	.229	.255	(40).240	.233	.104	.034
Erie	.243	.271	(50).257	.246	.106	.033
Huron	.241	.265	(50).253	.242	.106	.035
Lorain	.175	.198	(40).184	.181	.094	.031
Ottawa	.223	.250	(50).237	.223	.103	.032
Richland	.162	.182	(10).164	.164	.090	.032
Sandusky	.257	.285	(40).268	.255	.108	.032
Seneca	.225	.255	(40).237	.237	.105	.035
Wyandot	.252	.278	(30).260	.254	.108	.035
Ashtabula	.059	.072	(10).060	.060	.053	.024
Geauga	.045	.054	(10).046	.046	.044	.021

Table 8. Continued

County	Spring Plow Residue Left	Fall Plow Residue Left	Present Condition	Winter Cover	Conservation Tillage Mulch	Conservation Tillage No Till
Lake	.169	.193	(10).171	.164	.074	.021
Medina	.140	.160	(40).148	.144	.075	.028
Portage	.142	.159	(10).144	.144	.076	.029
Summit	.062	.078	(10).064	.064	.065	.030
Trumbull	.125	.142	(10).127	.127	.068	.025
Auglaize	.216	.241	(40).226	.220	.101	.032
Hardin	.243	.268	(40).253	.244	.107	.033
Mercer	.223	.249	(40).233	.225	.103	.033
Marion	.259	.286	(40).269	.256	.108	.033
Cuyahoga	.136	.157	(10).138	.135	.068	.021
			Michigan			
Monroe	.224	.248	(50).236	.236	.103	.034
Lenawee	.235	.259	(50).247	.238	.105	.034
Hillsdale	.156	.176	(30).162	.162	.090	.031
Wayne	.179	.199	(10).181	.181	.095	.034
Washtenaw	.115	.133	(10).117	.114	.062	.023
Jackson	.149	.168	(10).151	.151	.075	.027
Livingston	.089	.102	(10).090	.090	.074	.026
Oakland	.054	.066	(10).055	.055	.041	.018
MaComb	.148	.171	(10).150	.148	.083	.030
Lapeer	.071	.082	(10).072	.072	.058	.022
St.Clair	.068	.080	(10).069	.069	.054	.023
Sanilac	.066	.075	(10).067	.067	.060	.028

Table 8. Continued

County	Spring Plow Residue Left	Fall Plow Residue Left	Present Condition	Winter Cover	Conservation Tillage Mulch	Conservation Tillage No Till
			Indiana			
Allen	.250	.277	(50).266	.250	.108	.034
Adams	.257	.286	(50).271	.254	.108	.033
DeKalb	.239	.268	(50).254	.237	.106	.032
Noble	.221	.249	(40).232	.220	.102	.031
Stueben	.189	.215	(40).199	.189	.095	.029
Wells	.281	.312	(40).293	.274	.112	.033
			Pennsylvania			
Crawford	.078	.093	(10).080	.080	.053	.022
Erie	.091	.106	(10).093	.092	.054	.020
			New York			
Cattaraugus	.150	.172	(10).152	.152	.059	.021
Chautaugua	.079	.092	(10).080	.077	.047	.019
Erie	.083	.097	(10).107	.107	.068	.026
Wyoming	.105	.121	(10).107	.107	.068	.026
Niagara	.095	.110	(10).097	.097	.079	.027

*Percent of total tilled acreage that is fall-plowed.

<u>Woodland and Grassland</u>

1. The "C" values assigned in the SCS 1% Erosion Study for grasslands, idle and pasture, and for woodlands were accumulated during the review of slope length by soil and slope phases. The resulting data covers conditions throughout the Lake Erie basin and for all soils and slope phases.
2. It was recognized that a wide variety of conditions existed in the basin, but there was insufficient time for a county by county assessment of these conditions. The only relatively large data base available that was consistent over the basin was from the 1% Erosion Study.
3. Analysis of the "C" values confirmed a wide range of conditions both in the woodlands and grassland categories (Table 9). It was apparent that a straight averaging of the values would give a distorted picture. In order to evaluate the impact of the very high values (indicating very poor cover conditions) the top 10% of the entries were removed. It was found that they accounted for about 60% of the total summed values. This would suggest that there are significant potential sediment sources from these two land use categories. It also suggests that about 10% of each land use has the potential for producing the bulk of the erosion and resulting sediment.
4. Considering all of these factors, it appeared reasonable to use the median values as determined from the SCS Erosion Study for use across the basin. It must be kept in mind that there are areas that are much more severe and that slope conditions are not included; i.e. a poor cover condition (high "C" value) would typically be a greater sediment source on a steep slope than on a flat slope.

5. Assignment - Grasslands, pasture and idle = .003

This equates to 95-100% ground cover and can include a canopy of 25-50% of brush and bushes.

6. Assignment - Woodlands = .005

This equates to a medium stocking of trees, at least a 50% canopy and good litter cover over about two thirds of the ground surface.

Division of Forestry in five counties in Cleveland area described canopy and litter conditions equal to those described in SCS Technical Guide as equal to a "C" value of 0.005.

Table 9 . C values assigned to Lake Erie basin grassland and woodland in SCS 1% Erosion Study.

Grasslands, pasture and idle land

308 separate observations with gross summed value of 9.231

Range in values	.001-.45
Average value	.0299
Median value	.003

Highest 10% of observations (31) account for 59% of total

gross value	5.435
average value of remaining 90%	.013
median value of remaining 90%	.003

147 observations were of .003

Woodlands

284 separate observations with gross summed value of 7.083

Range of values	.001-.99
Average value	.0249
Median value	.005

Highest 10% of observations (28) account for 63% of total

gross value	4.481
average value of remaining 90%	.010
median value of remaining 90%	.003

149 observations were .005 or less

Vineyards

1. A field visit was made to the Soil Conservation Service office at Jamestown, New York in June, 1978. Mr. Brown, District Conservationist, discussed grape culture as practiced in western New York. Mr. T.D. Jordan, Extension Service grape specialist at Fredonia, New York, was consulted on grape fertilization, tillage, erosion, and chemical use.

2. A summary of their comments follow:

   a) Typical grape culture calls for cultivation from mid-May to about mid-August. At this time, native grass vegetation is allowed to come back or seedings of ryegrass, barley, wheat or rye are made. Cultivation by disking is only done for about a 3-month period.

   b) Prunings per vine vary from 2-4 pounds with 640-800 vines per acre; 1000-2000 pounds of trimmings are chopped with a rotary mower and incorporated along with the sod or cover crop by two or three diskings from May until August.

   c) It was felt that, because of the sod or cover crop plus the trimmings, even though disking is done for 3 months of the year, there is little potential for erosion from vineyards. Clean cultivation is typically not used or recommended. Observations confirm this although one vineyard observed did have all vegetation destroyed and was clean tilled. This did seem to be the exception.

   d) Cover factors differ greatly between the Lake Plain area with heavy poorly-drained and somewhat poorly-drained soils (heavy inclues silt loam) and the moderately well and well-drained gravelly outwash soils of the sloping uplands. This is the result of poorer cover from native grasses and less vigor of the vines resulting in fewer prunings from the vineyards on the Lake Plain.

Based on these comments and general observations during 1-1/2 years of driving through the grape growing areas of Ohio, New York, and Pennsylvania,

it seems appropriate to accept the "C" values established in the SCS Technical Guide for Chautauqua County, New York.

The following "C" values were used for all vineyards in the Lake Erie basin:

Tillage Group 1 soils - .02*

Tillage Group 2, 3, 4, and 5 soils - .09**

THE USLE SCENARIOS

Selection of Management Scenarios

The USLE was used with the LRIS data base to assess potential reduction of gross erosion by various cropping and management system options. These would include: a) reducing existing soil loss to the soil loss tolerance (T) value for those soils which exceeded T, with no treatment for soils already at or below T; b) ban the use of fall-plowing and substitute spring plowing; c) employ a winter cover crop with fall plowing to protect soil surface during winter and early spring runoff; d) use conservation tillage (chisel plow, disk, etc) or no-till to reduce soil loss.

Based on these considerations, nine USLE calculations were made:

1. Existing conditions - assumed no conservation tillage and variable percentages of each county fall-plowed.
2. Conform to the T factor - only those soils currently experiencing soil loss greater than T were considered. Soil loss was reduced to T yielding total soil loss equal to T.
3. Soil loss less than T - in this run, soil loss from soils with erosion less than T was determined for existing conditions as in (1) above.
4. Soil saved at T - this run calculates the reduction in soil loss when soils above T are reduced to T and soils below T are untreated. Run No. 4 is equal to: 1 - (2+3), i.e. the difference between existing conditions in the basin and soil loss $\leq$ T for all soils.

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* Represents 3# of trimmings per vine and good permanent cover.
** Represents 2# of trimmings per vine and poor to fair permanent cover

5. Spring plow - assumed that all soils are spring moldboard plowed and that crop residue was not removed after previous crop harvest.
6. Fall plow - assumed that all soils are fall moldboard plowed and that crop residue was not removed after previous crop harvest.
7. Winter cover - assumes that a cover crop will be planted in the row crop part of the rotation when land is fall-plowed.
8. Mulch tillage - this run assumed that some alternative to moldboard plowing (chisel, disk, rotary hoe, etc) would be used, and that an average of 1500-2000 pounds of crop residue per acre would remain after tillage.
9. No-till - no-till methods used on all soils to give an average of 3000-4000 pounds/acre of crop residue.

An example of the USLE output is given in Table 10 for the Maumee River Basin drainage area above the USGS gaging station at Waterville, Ohio. In this case, the output is for the entire drainage area above the gage, but in addition, the USLE output was determined for counties or portions of counties in a particular watershed or subbasin. The USLE output (Table 10) was determined for soils in each soil management group and also summarized for all cropland, grassland and woodland. Table 10 gives the tons of erosion per year in each category, acres in each category and the unit area soil loss (tons/acre/year). <u>Appendix I to this report published separately (LEWMS, 1979) gives the complete output for the Lake Erie Basin</u>.

<u>Soil Loss Reduction Strategies</u>

Although the individual runs discussed previously provide significant information on the relative impact of practices by SMG in a particular watershed, it is not reasonable to expect that some of these practices would be adopted by basin farmers on all soils. Farmers, for example, are not likely to use no-till

Table 10. An example of the USLE output for the nine initial runs.

ARMY CORPS OF ENGINEERS BUFFALO DISTRICT: LEWNS ESTIMATION OF POTENTIAL GROSS EROSION BY USLE AND LRIS(MAIN FILE) MAUMEE @ WATERVILLE SAMPLING STATION NO. 1 STA. TYPE:LOWST IN BSN CO: ALL IN BASIN COUNTY NUMBER: 62	1 PRESENT CONDITION TONS/YR ACRES T/A/YR C1 SCENAR 1	2 CONFORM TO TFAC IF PGE GT TFAC TONS/YR ACRES T/A/YR (SCENARIO 2=2+3)	3 PRESENT CONDITION IF PGE LE TFAC TONS/YR ACRES T/A/YR	4 SOIL SAVED IF TFAC MET 4=1-(2+3) TONS/YR ACRES T/A/YR	5 SPRING PLOWED RESIDUE LEFT TONS/YR ACRES T/A/YR C2 SCENAR 3	6 FALL PLOW RESIDUE LEFT TONS/YR ACRES T/A/YR C3	7 WINTER COVER TONS/YR ACRES T/A/YR C4 SCENAR 6	8 CONSERV. TILL: MULCH TONS/YR ACRES T/A/YR C5	9 CONSERV. TILL: NO TILL TONS/YR ACRES T/A/YR C6
CROPLAND	3247739.0	862316.9	252812.8	2132605.0	3080880.0	3422547.0	3098335.0	1382706.C	439860.3
SMG	345199.0	248740.3	95035.1	248740.3	345199.0	345199.0	345199.0	345199.0	345199.0
1	9.41	3.47	2.66	8.57	8.92	9.91	8.98	4.01	1.27
CROPLAND	3471857.0	1591145.0	487838.9	1392823.0	3292560.0	3651917.0	3310101.0	1444185.0	458046.8
SMG	822057.9	526429.7	295539.0	526429.7	822057.9	822057.9	822057.9	822057.9	822057.9
2	4.22	3.02	1.65	2.65	4.01	4.44	4.03	1.76	0.56
CROPLAND	505374.4	255516.2	164368.6	85489.6	477334.6	526911.1	480815.9	212237.2	69368.9
SMG	143891.5	85646.6	58245.1	85646.6	143891.5	143891.5	143891.5	143891.5	143891.5
3	3.51	2.98	2.82	1.00	3.32	3.66	3.34	1.47	0.48
CROPLAND	475736.2	0.0	475736.2	0.0	450840.4	499346.2	451086.0	194250.7	61042.0
SMG	500139.6	0.0	499516.5	0.0	500139.6	500139.6	500139.6	500139.6	500139.6
4	0.95	0.0	0.95	0.0	0.90	1.00	0.90	0.39	0.12
CROPLAND	207113.1	10548.9	134299.6	62204.6	195929.1	216646.6	197476.3	87296.4	28351.2
SMG	125167.6	3590.4	121577.2	3590.4	125167.6	125167.6	125167.6	125167.6	125167.6
5	1.65	2.94	1.10	17.34	1.57	1.73	1.58	0.7C	0.23
CROPLAND	6685.8	177.9	4701.6	1746.2	6261.7	6799.8	6466.9	2820.1	1006.9
SMG	2135.0	89.0	2046.0	89.0	2135.0	2135.0	2135.0	2135.C	2135.0
7	3.13	2.00	2.33	19.63	2.93	3.18	3.03	1.32	0.47
CROPLAND	503811.0	0.0	503811.0	0.0	473396.6	522161.3	472718.1	200387.1	63594.5
SMG	403720.0	0.0	403720.0	0.0	403720.0	403720.0	403720.0	403720.0	403720.0
8	1.25	0.0	1.25	0.0	1.17	1.29	1.17	0.5C	0.16
CROPLAND	354682.8	3202.5	297888.2	53592.1	334004.7	366830.9	337493.5	145835.7	48482.7
SMG	251083.3	1601.2	249482.1	1601.2	251083.3	251083.3	251083.3	251083.3	251083.3
9	1.41	2.00	1.19	33.47	1.33	1.46	1.34	0.58	0.19
CROPLAND	319447.5	9452.6	0.0	309994.8	301193.7	332300.1	304082.1	132217.4	43206.0
SMG	3351.4	3351.4	0.0	3351.4	3351.4	3351.4	3351.4	3351.4	3351.4
10	95.32	2.82	0.0	92.50	89.87	99.15	90.73	39.45	12.89
* SUMMARY *	9092447.0	2732355.3	2321560.0	4038532.0	8612403.0	9545462.0	8658573.0	3801932.C	1212955.0
* CROPLAND *	2596736.0	869448.6	1725158.0	869448.6	2596736.0	2596736.0	2596736.0	2596736.0	2596736.C
* SMG 1-10 *	3.50	3.14	1.35	4.64	3.32	3.68	3.33	1.46	0.47
VINEYD &	674.3	266.9	258.7	148.7					
ORCH,SMG	356.5	89.0	267.6	89.0					
1	1.891	3.000	0.967	1.671					

Table 10. Continued.

VINEYD &	160.6	0.0	160.6	0.0						
ORCH,SMG	170.6	0.0	170.6	0.0						
2	0.941	0.0	0.941	0.0						
VINEYD &	26.9	0.0	26.9	0.0						
ORCH,SMG	89.0	0.0	89.0	0.0						
4	0.302	0.0	0.302	0.0						
VINEYD &	30.9	0.0	30.9	0.0						
ORCH,SMG	109.0	0.0	109.0	0.0						
5	0.284	0.0	0.284	0.0						
* SUMMARY *	892.7	266.9	477.1	148.7						
* VINFORCH *	725.1	89.0	636.1	89.0						
* SMG 1-10 *	1.231	3.000	0.750	1.671						
GRASSLAND	7992.9	0.0	7992.9	0.0						
	113768.0	0.0	113679.1	0.0						
	0.070	0.0	0.070	0.0						
WOODLAND	27489.6	711.7	26671.9	106.1						
	282527.9	355.8	281994.2	355.8						
	0.097	2.000	0.095	0.298						
* SUBTOTAL *	9128805.0	2733334.0	2356694.0	4038777.0	8648764.0	9581825.0	8694938.0	3838295.0	1249326.0	
* *	2993747.0	869893.4	2121458.0	869893.4	2993747.0	2993747.0	2993747.0	2993747.0	2993747.0	
* *	3.05	3.14	1.11	4.64	2.89	3.20	2.90	1.28	0.42	
WATER AREA ONLY	105637.1									
OTHER LAND USE AREA ONLY	323877.1									
MISSING LAND USE AREA ONLY	238.7									
MISSING SOILDATA AREA ONLY	637869.4									
MISSING LU & SOIL AREA ONLY	2145.0									

on SMG3 soils because of reduced yields (e.g. on SMG's 3, 5, 7 and 9). Therefore, the nine USLE runs were reduced to seven management scenarios, and described below and summarized in Table 11.

Scenario 1 is the present conditions scenario. Potential gross erosion (PGE) is calculated for each of the 62 counties in the Lake Erie drainage basin for the best estimate of prevailing conditions in each.

Scenario 2 evaluates the effect of limiting PGE across the basin to T, the soil loss tolerance factor. The T factor is the upper limit of PGE which a soil in crop production can withstand over the long-term without reduction in crop yield. For any given soil resource unit, it is the standard or goal to reach in the development of conservation plans for farm units. Thus, in Scenario 2, the assumption is made that all farms in the Lake Erie basin have fully implemented conservation plans in effect. For any cell in which the present PGE is less than T, the present condition is unaltered.

Scenario 3 alters the present condition by eliminating the practice of fall plowing.

Scenario 4 is the inverse of Scenario 3 in that the soil loss equation is evaluated for fall plowing only. Although this is a scenario which increases PGE, it was necessary to assess the range of soil loss which might be expected from an increase in fall plowing and a decrease of the spring plowing.

Scenario 5 requires the introduction of a winter cover crop planted in the residue of the previous crop. Spring tillage precedes the next crop.

Scenario 6 is the most extreme of the scenarios. It requires the maximum PGE reduction practically achievable through the use of tillage modification. Before tillage modification is allowed on a particular soil in this scenario, that soil must be identified as "suitable" or not having significant adverse impacts on net farm income. The no-till crop production

Table 11. Potential gross erosion (PGE) scenarios for the Lake Erie Drainage Basin

Scenario	Soil Management Group (SMG)									
	1	2	3	4	5	6	7	8	9	10
1. Present Condition	PC	PC	PC	PC	PC	PC	PC	PC	PC	PC
2. Reduce Soil Loss to T and Existing	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T	T=PC T=T
3. Spring Plow Only	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
4. Fall Plow Only	FP	FP	FP	FP	FP	FP	FP	FP	FP	FP
5. Winter Cover Crop	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC
6. Conservation Tillage	NT	NT	PC	MT	PC	NT	PC	MT	PC	NT
7. Reduced Tillage	MT	MT	PC	MT	PC	MT	PC	MT	PC	MT

PC: Present Condition

T=PC: If the existing potential gross erosion calculated for a cell is less than the soil loss tolerance factor, PGE remains as the present condition.

T=T: If the existing PGE calculated for a cell is greater than the soil loss tolerance factor for the soil, PGE is set equal to T.

SP: Implies the use of spring moldboard plow tillage only as an alternative to present conditions.

FP: Implies the use of fall moldboard plow tillage as an alternative to present conditions. This will usually imply an increase in PGE.

WC: Requires the introduction of a winter cover crop following some fall tillage. Remaining tillage is performed in spring.

NT: No-tillage. Crop is planted directly in the residue of the previous year's crop.

MT: Mulch tillage. Applied as fall reduced tillage (chisel, disk, rotary hoe, etc).

system is applied on SMGs 1, 2, 6, and 10; chisel plowing (fall or spring, depending on current timing) is utilized on SMGs 4 and 8; and present practices (predominantly fall moldboard plowing) are continued on SMGs 3, 5, 7, and 9.

Scenario 7 is an intermediate reduced tillage scenario which requires the use of the chisel plow (again, in fall or spring as presently used) on SMGs 1, 2, 4, 6, 8, and 10, while continuing the allowance of present practices on SMGs 3, 5, 7, and 9.

In addition to the cropland, vineyards and orchards, pastureland, and woodland soil loss values, there are soil loss values developed for those areas which appear as missing data. Missing data represents those cells for which no soils information is available due to lack of available published soil survey maps.

For areas missing soil data, the assumption was made that land use distribution for missing data was the same as the land use distribution for which soils information was available. The average soil loss values in tons per acre per year for the particular land use with soils data was assigned to those assumed land uses with missing soil data.

Excluded from the soil loss totals for the various scenarios are soil losses from water areas which have no soil loss and soil losses from other land use areas. These other areas include such land uses as: commercial, industrial, residential, public utilities, developing areas, extractive, and transportation lands. While it is known that these areas do indeed have soil loss problems, there was no methodology established to estimate the extent of soil loss. In many cases, these land uses have more gully erosion problems which can be considered "identifiable non-point sources". Where other land use categories represent a high percentage of the land area, for example, in the river basins draining the Detroit or Cleveland metropolitan areas, this problem is significant. However, on a lakewide basis it is not important.

When evaluating the results of the following scenarios, keep in mind these points: Each data point represents a landscape cell of between 10 and 90 acres, each scenario option is assumed to be adapted totally for those Soil Management Groups where it is suitable. Scenario 6 assumes that adequate subsurface drainage has been installed in all Group 2 and 6 soils.

The object was to determine the total possible reduction in PGE that would be accomplished under ideal conditions using only tillage and cover modifications. Ideal conditions will not be achieved for a number of reasons. The normal intermingling of both adaptable and unadapted soils for a given scenario within a field precludes total adaption. All Group 2 and 6 soils do not have adequate subsurface drainage. None of the scenarios tested will achieve the allowable soil loss limits for Group 10 soils. A land use change, rotation change or structural means will be required for Group 10 soils.

Table 12 is an example of the results obtained by running the scenarios program on the raw USLE output. This table takes into account the economic constraints of reduced tillage as described above. For example, the PGE for SMG3 is the same under the Conservation Tillage (Conservation Tillage in Table 10 is the same as Maximum Reduction Tillage in Table 12) scenario as under existing, and SMG 4 remains under this scenario with the PGE rate achieved under the Reduced Tillage scenario. At the bottom of Table 12, the Summary Total Potential Gross Erosion is given for each scenario. This total adds all land uses together and extrapolates PGE for the missing data area. The final line is the percent reduction relative to existing conditions for each scenario. At the right side of the table the PGE rate for all lands currently exceeding the soil loss tolerance limit is given for each SMG. This column gives an indication of the conservation needs in a given county or watershed.

Table 12. Example output of soil loss reduction scenarios (Maumee River Basin above Waterville, Ohio).

LAKE ERIE WASTEWATER MANAGEMENT STUDY U.S. ARMY CORPS OF ENGINEERS, BUFFALO DISTRICT
LAND MANAGEMENT ALTERNATIVES : BEST MANAGEMENT PRACTICE SCENARIOS

BASIN: MAUMEE RIVER WATERVILLE,OH COUNTY: 62 ALL IN BASIN

LAND USE	EXISTING POT. GROSS EROSION (TONS) (TONS/ACRE)	REDUCE SOIL LOSS TO T AND EXISTING (TONS) (TONS/ACRE)	SPRING PLOWING ONLY (TONS) (TONS/ACRE)	FALL PLOWING ONLY (TONS) (TONS/ACRE)	WINTER COVER CROP (TONS) (TONS/ACRE)	MAXIMUM REDUCTION TILLAGE (TONS) (TONS/ACRE)	REDUCED TILLAGE: CHISEL PLOW (TONS) (TONS/ACRE)	SOIL MGMT. GROUP LAND AREA (ACRES)	EXISTING SOIL LOSS > T FACTOR (ACRES) (TONS/ACRE)
CROPLAND	3247739.0	1115129.7	3080860.0	3422547.0	3098335.0	439860.3	1382706.3	345199.0	246740.3
SMG 1	9.4	3.2	8.9	9.9	9.0	1.3	4.0		12.0
CROPLAND	3471857.0	2079033.9	3292560.0	3651917.0	3313101.0	458046.8	1444185.0	322057.3	526429.7
SMG 2	4.2	2.5	4.0	4.4	4.0	.6	1.8		5.7
CROPLAND	505374.4	419884.8	477334.6	526911.1	480815.9	505374.4	505374.4	143391.5	85646.6
SMG 3	3.5	2.9	3.3	3.7	3.3	3.5	3.5		4.0
CROPLAND	475736.2	475736.2	450840.4	499346.2	451086.0	194250.7	194253.7	500139.6	0.0
SMG 4	1.0	1.0	.9	1.0	.9	.4	.4		0.0
CROPLAND	207113.1	144848.5	195929.1	216646.6	197476.3	207113.1	207113.1	125167.6	3590.4
SMG 5	1.7	1.2	1.6	1.7	1.6	1.7	1.7		20.3
CROPLAND	6685.8	4939.5	6261.7	6799.8	6466.9	6585.8	6685.3	2135.3	89.0
SMG 7	3.1	2.3	2.9	3.2	3.0	3.1	3.1		21.6
CROPLAND	503811.0	503811.0	473396.6	522161.3	472718.1	200387.1	200387.1	403720.0	0.0
SMG 8	1.2	1.2	1.2	1.3	1.2	.5	.5		0.0
CROPLAND	354682.8	301090.7	334004.7	366830.9	337493.5	354682.8	354682.3	251083.5	1601.2
SMG 9	1.4	1.2	1.3	1.5	1.3	1.4	1.4		35.5
CROPLAND	319447.5	9452.6	301193.7	332300.1	304082.1	43206.0	132217.4	3351.4	3351.4
SMG 10	95.3	2.8	89.9	99.2	90.7	12.9	39.5		95.3
CROPLAND	9092446.8	5053926.9	8612400.8	9545460.0	8658574.8	2409607.0	4427602.3	2596745.3	
	3.5	1.9	3.3	3.7	3.3	.9	1.7		
VINEYARDS	892.7	744.0 (TONS)	WATER		105637.1 (ACRES)				
AND ORCH.	725.1	725.1 (ACRES)	AREA ONLY						
	1.23	1.03 (TONS/ACRE)							
GRASSLAND	7992.9	7992.9 (TONS)	OTHER LAND		323877.1 (ACRES)				
AND PASTURE	113768.0	113679.1 (ACRES)	USE AREA						
	.07	.07 (TONS/ACRE)							
WOODLAND	27489.6	27383.6 (TONS)	MISSING DATA		640253.1 (ACRES)				
	282527.9	282350.0 (ACRES)							
	.10	.10 (TONS/ACRE)							
SUMMARY TOTAL POTENTIAL GROSS EROSION	11081130.9	6179701.7	10498421.3	11631026.4	10554470.1	2969085.1	5418653.0	3634319.4	
	3.0	1.7	2.9	3.2	2.9	.8	1.5		
PERCENT REDUCTION:	0.0	44.2	5.3	-5.0	4.8	73.2	51.1		

These scenario reports have been prepared for each county portion of watersheds and in summary for each major and minor sampling station watershed in the Lake Erie basin. These reports are reproduced in total in another of the LEWMS Technical Reports, "Land Management Alternatives for the Lake Erie Drainage Basin" (LEWMS, 1979).

These seven land management scenarios are used in the Phase II Feasibility Report (LEWMS, 1979) in conjunction with the calculation of phosphorus load reductions.

OBSERVATIONS

Based on the results of the USLE analysis, a number of observations can be made:

1. Potential gross erosion, as soil loss throughout the Lake Erie basin, can be reduced to only about 30 percent of existing levels through the adoption of no-tillage and reduced tillage cropping management systems wherever economically feasible.
2. 100 percent adoption of conventional conservation plans to hold soil loss at or below the soil loss tolerance limit, T factor, would reduce basinwide soil loss by only 40 percent, a reduction which would be inadequate to achieve the total phosphorus loading objective for Lake Erie.
3. The lack of reduction in soil loss by adoption of spring plowing and winter cover crops is deceptive. Although we can conclude from this analysis that soil loss would not be greatly reduced through these practices, the maintenance of cover during the winter-spring sediment transport period would have a significant effect on water quality.
4. The USLE/Scenario analysis is a useful tool for estimating the environmental impacts of the adoption of a variety of land management options. It is clear though that a direct relationship with water quality impacts, through the sediment and nutrient transport mechanism, does not exist. The results of the analysis must be considered in relative terms.

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